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MTMC CONUS Movement Scheduling Program

FINAL REPORT

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Report of technical assistance to the Military Traffic Management Command (MTMC) in the development of the capability for the analysis and scheduling of CONUS movements by computer for mobilization and deployment planning. Several recommended remedial measures are included.

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This final report incorporates the comments of the HQ MTMC Plans Division which were very helpful.

SECTION 1

SUMMARY

INTRODUCTION

This report covers the work prescribed in the task entitled "MTMC CONUS Movement Scheduling Program" in Contract Number MDA903-79-C-0172. The purpose of this task order is to provide technical assistance to the Military Traffic Management Command (MTMC) in the development of the capability for the analysis and scheduling of CONUS movements by computer for mobilization and deployment planning in support of operation planning or other special projects. The full tasking statement is in Appendix A.

BACKGROUND

Deployment Scheduling and Analyses

Deployment movement scheduling by the MTMC is now based on MAPS (Mobility Analysis and Planning System), a computerized simulation system that suffers from serious defects in structure, logic, and usage (see Table 1). This situation is apparently the result of many factors including development of the original system concept in 1966, transfers of system responsibility from one headquarters to another, reprogramming from one computer system to another, piecemeal efforts to amplify the scope of the system to be compatible with evolving JCS planning systems and reporting requirements. A detailed account of the development of MAPS is in Appendix B. The resulting difficulties are well known, and only the major ones are summarized below:

- Inability to respond rapidly to planning tasks.
- Inability to perform mobility analyses of two or more theaters simultaneously.
- Large expenditures of overtime resources in efforts to meet planning deadlines.
- Lack of adequate credibility of the output of MAPS and the manual resolution of movement requirements not scheduled by MAPS.
- Inability to integrate mobilization and deployment movement planning.

TABLE 1

MAJOR DEFICIENCIES IN MAPS SCHEDULING SYSTEM

STRUCTURAL DEFICIENCIES

- Running time is excessive (over 18 hours)
- Documentation is incomplete and not fully understandable
- No programs for providing the analyst with summary data for preliminary analyses and understanding of the problems involved before scheduling is started
- Unable to accept changes to individual elements without rerunning the entire file (e.g., change in berth time for a ship)
- Inflexible programs with no provision for interaction with the analyst or running separate parts independently and consequently no computer capability to resolve "flags"
- No report writer; each report must be specifically programmed
- No programs for determining earliest possible arrival time of "flagged" movements
- No data base; all files are not logically related

LOGIC DEFICIENCIES

- Treats each scheduling requirement sequentially as a separate problem with no optimization features (e.g., no effective capability to consolidate shipments either at origins or POEs by computer)
- Port selection criteria minimize use of land travel, with consequent inability to handle Europe- and Pacific-oriented plans concurrently
- No provision for trade-off between rail and motor capacities when both modes are used simultaneously at origins
- Assumes that (1) rail cars, trucks, and ships are available as needed; (2) that there are no constraints on holding capacity at ports, and (3) that there is a fixed time to load ships regardless of cargo to be loaded and port facilities
- No provisions for RO/RO ships

USAGE DEFICIENCIES

- The level of detail treated is unwarranted by the data. Costly time consuming manual effort is expended on lines that comprise far less than 10% of the tonnage to be moved
- No provision for integrated analyses of deployment and mobilization (INCONREP) movement requirements (currently treated sequentially)
- Excessive number of ports and manual effort used to resolve "flags" because MAPS is oriented on meeting latest arrival date (LAD) with consequent movement of many ships loaded far below capacity.

Interface with Other Transportation Operating Agencies

Military Airlift Command (MAC)

There are no significant interface problems between the MTMC and the MAC. MAC specifies the Air Port of Embarkation (APOE) and the time for the arrival there of passengers and cargo. The MTMC responsibility ends with the delivery of the passengers and cargo at the APOE.

Military Sealift Command (MSC)

The overall current system for deployment planning is severely handicapped by the division of responsibility in the planning for movement requirements using sea transportation. The MTMC is responsible for that part of the requirement starting at the origin and ending with a ship loaded by the MTMC at a port selected by the MTMC. The MSC is responsible for the planning that involves furnishing ships at the ports designated by the MTMC and the onward movement to the port of debarkation (POD). The interface between the MTMC and the MSC is poor, there is no commonality between their models, and as a result, the MTMC scheduling is based on the use of notional ship speeds and capacities and assumes ships are available as required.

DISCUSSION

A fundamental defect of the MAPS scheduling system is the lack of any optimization procedures. MAPS is a pure simulation that treats each movement requirement in turn as a separate problem. Coupled with the lack of a front-end analysis capability, treatment in detail beyond that warranted by the data, and rigid planning assumptions, MAPS results in:

- About 20% computerized output and 80% manual output to complete a deployment analysis
- Inability to cope with a number of mobility planning problems (multi-theater plans and integrated mobilization and deployment planning).

The lack of adequate documentation in MAPS precludes any efforts to modify the scheduling programs to remedy the major defects cited in Table 1. The documentation provided[1] indicates that efforts to modify the scheduling programs would be very time consuming and costly, particularly in view of the logic deficiencies indicated in Table 1. Consequently, a new model or sets of programs are required for movement scheduling.

Optimization

Currently, linear programs for optimization of large and complex problems such as those addressed by MAPS are extremely difficult, if at all possible, to formulate and require very long times to run. Further, the output of these linear programs is difficult to explain.

Recent developments in the field of mathematical programming[2] give promise of permitting relatively rapid formulation and solution of large problems such as the CINC Operations Plans presented to the MTMC. Even if a practical mathematical programming technique can be found for an optimization model for scheduling movement requirements now handled by MAPS, it will still be necessary to have a supporting simulation model to produce the types of detailed data required from the MTMC, by the JCS, the other TOAs, and for the MTMC internal planning.

"Front-End" Analysis and Aggregation

One approach to reducing the number of movement scheduling requirements is to provide the analyst(s) with (1) summary data on all the movement requirements in the plan(s) for "front-end" analysis before scheduling starts, and (2) programs for aggregating lines and FRNs with small tonnages (level to be set by the analyst). The provision of such

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[1] Larry Bobo, "System Description for Mobility Analysis and Planning System (MAPS)," MTMC, 1 March 1979.

[2] Hindelang, Thomas J., and John F. Muth, "A Dynamic Programming Algorithm for Decision CPM Networks," Operations Research, March-April 1979, and Glover, F., J. Hultz, D. Klingman and J. Stutz, "Generalized Networks: A Fundamental Computer-Based Planning Tool," Management Sciences, August 1978.

summary data and aggregation programs would permit early decisions by the analyst on movement requirements that are either inconsequential and need not be scheduled or that can be aggregated and still be within the feasibility limitation (± 10%) prescribed by the Joint Operation Planning System (JOPS). In this manner, the workload in terms of computer running time and manual effort can be reduced.

The capability to provide summary data and aggregation routines would be of utility with any movement planning system.

Network Analyses

MAPS is a rigid system that minimizes land transit (i.e., movement from origin to nearest available port). There are transportation modeling techniques with proven algorithms that can be readily modified to meet the MTMC movement scheduling needs. These techniques are based on defining a transportation system in terms of links and nodes. Links represent roads, rail lines, sea routes, and transfer capacities (receive and outload) from one mode to another. Nodes are used to represent origins, POEs, and destinations. The major advantage of this type of representation is the proven special-purpose algorithms that permit extremely rapid movement scheduling over large networks (2000 links).

These algorithms are flexible and permit the analyst to exercise various options. As currently used, they normally minimize the total transit time. Hence, they are of particular use in integrated mobility analysis of multi-theater movement plans. After suitable modification in combination with the summary data and aggregation programs previously described, such algorithms should eliminate most of the MAPS major defects cited in Table 1. The modified algorithms, referred to hereafter as NETWORK, would:

- Be capable of analysis of both single and multi-theater movement plans.
- Integrate mobilization and deployment movement planning analyses.

- Minimize total transit time.
- Reduce, if not eliminate completely, need for manual resolution of flags.
- Provide estimated earliest date of arrival at the POE (POD) if there are movement constraints and identification of the governing constraints.
- Provide certain interim reports.

The NETWORK algorithms or model are described in detail in Section 3.

Modularity

One way to increase the responsiveness of MAPS or any other movement scheduling system is to take advantage of the relatively independent nature of certain types of movements. For example, ammunition moves through dedicated SPOEs. The origins of ammunition shipments are from dedicated points except for three locations. Air passengers do not affect an origin's capability to receive or ship by truck or rail. Scheduling mutually exclusive groups of movements, such as ammunition, air passengers, and cargo should decrease computer data storage problems and increase planning responsiveness. Currently MAPS ammunition and cargo are scheduled together in accordance with certain internal priorities. By adapting the modular approach outlined above, analysts working with ammunition and cargo, for example, can complete their work independently. There are no problems foreseen in resolving the three origins common to ammunition and cargo. The modular approach will be incorporated into the NETWORK model.

Other significant advantages of modularity are reduction in data storage problems and increased flexibility in the use of available computer time.

Interface Problems

The resolution of the interface problems between the MTMC and the MSC will probably require an extensive period of negotiations. Pending the

resolution of these problems, there are several measures that might be taken by the MTMC to improve the quality of deployment planning. These measures are discussed below.

The speeds and capacities of the notional ships used by the MTMC should be closely coordinated with the MSC and consideration given to the use of notional slow and fast ships. Further, a notional RO/RO ship should be established to permit planning for use of such ships.

The MTMC must consider the time and distance for the sea leg of movements from origin to POD in scheduling arrivals at the SPOE. However, due to the lack of complete information on ship schedules and types, it is questionable whether it is sound for the MTMC to "flag" shipments because of sea movement constraints or attempt to resolve such constraints by use of an excessive number of ports (berths) and loads far below ship capacity. Consideration should be given to emphasis on the movement of cargo to ports in shipload quantities as nearly as possible, in accordance with the CINC priorities and having the MSC determine if the sea leg can be accomplished by the latest arrival date (LAD) at the POD.

CONCLUSIONS

1. The current methods (MAPS and manual procedure) used by the MTMC for movement scheduling are inefficient and flawed in logic. The faults inherent in MAPS for movement scheduling are so great as to preclude any effort to modify the existing scheduling programs.

2. There is an immediate need for programs to produce a summary data for analysis and to permit aggregation, at levels designated by the analyst, of FRNs and lines with small tonnages before the start of movement scheduling. These preprocessing programs should be based on the Master Requirement Record produced by the MAPS for the given operation plan(s).

3. There is an immediate need for a new and well-documented movement scheduling program or model that is compatible with the other elements of MAPS, JOPS, and the computer equipment at the MTMC.

4. Research should be undertaken to determine whether recent advances in mathematical programming will permit development of a feasible optimization model for the MTMC movement scheduling requirements. Such a model would provide inputs to simulation models to produce the detailed data required by the MTMC for internal use and in support of the JOPS.

RECOMMENDATIONS

1. A "Quick Analysis and Aggregation" option to develop the programs described in Conclusion 2 should be adopted. This option is described in Section 2.

2. Concurrent with the previous recommendation, a new movement-scheduling model called NETWORK should be developed. This model, described in Section 3, is built on existing proven transportation network algorithms.

3. Research should be undertaken to investigate the feasibility of using optimization techniques as part of movement scheduling. This proposed research is described in Section 4.

RESOURCE ESTIMATES

The estimated resource requirements for implementing the recommendations are listed below:

Option	Calendar Months	Technical Person-Months	Cost
1 Quick Analysis and Aggregation	4	7	$ 40,000
2 Network	11*	20	148,000
3 Research	3	2	18,000

*Includes time for documentation after the model has been made operational.

SECTION 2

QUICK ANALYSIS AND AGGREGATION (QA^2) OPTION

OBJECTIVES

To reduce the current manual workloads and decrease the time required in analyzing and testing the feasibility of operations plans derived from the Joint Operations Planning System.

METHOD

The objectives are to be accomplished by:

- Automated preparation of summary tables for analysis and decisions prior to operation of the current MAPS scheduling program or any comparable program
- Provision of an automated capability to aggregate FRNs and lines, if desired, at levels determined by the analyst
- Provision of the capability to schedule separately the following types of movements under the NETWORK option
    - Ammunition
    - Air passengers
    - Cargo (other than ammunition)

In accomplishing the objectives the following principles will apply:

- The MAPS Master Requirement Record File (File ID41004B) will be preserved at all times. All work in the proposed plan is to be done on a copy of the MAPS Master Requirement Record.
- No change is planned in current MAPS logic or outputs whether or not the NETWORK option is implemented (see Section 3).

SUMMARY TABLES

GRC will prepare, debug, and document programs to produce tables 2-34, outlines of which are appended. These tables are designed to permit preliminary analysis of the plan(s), and to permit analyst

decisions on levels of aggregation and the sequence and scope of the scheduling to be performed by the current MAPS system, or substitute system such as NETWORK. These tables are briefly described below.

Table 2

Shows the total movement requirements by LAD in 10-day increments by air passengers, and sea and air short and measurement tonnage for ammunition, unit cargo, and resupply cargo. The analyst will have the option of specifying a constant LAD increment for each run. Additional cargo categories such as sea passengers, container and non-container ammunition and resupply cargo, etc. will be included in the tables as required by MTMC.

Tables 3-10

These tables show the short and measurement tonnages for the total plan, ammunition, unit cargo, and resupply cargo in terms of origins and destinations. Separate tables cover the air and sea movement of the four groups. Additional cargo categories such as sea passengers, container and non-container ammunition and resupply cargo, etc. will be included in the tables as required by MTMC.

These tables permit the analyst to determine, among other things, those sea destinations that receive an insignificant amount of tonnage for the purpose of the plan. Provision will be made to delete such destinations from further consideration in the planning process, at the option of the analyst. In the deletion process the FRNs and lines involved will be printed out so that the other TOAs concerned can be informed.

Tables 11-18

These tables show the same data as above but in terms of origins and the planned LAD in 10-day increments. The analyst will have the option of specifying a constant LAD increment for each run.

Tables 19-26

These tables show the same data as above but in terms of destinations and the planned LAD in 10-day increments. The analyst will have the option of specifying a constant LAD increment for each run.

Tables 27-34

These tables provide detailed analyses for the entire plan, ammunition, resupply cargo, unit cargo, in terms of numbers of FRNs and lines concerned and the tonnages associated with the FRNs and lines by origin and associated destinations, and relation to the total tonnages involved. Separate tables are provided for sea and air movement of each of the four groups. The tables provide for a count of FRNs and lines and associated tonnages within the breakout of up to and including 10 tons, 10.1 to 20 tons inclusive, and more than 20 tons. These brackets can be varied by the analyst.

These tables provide a basis for decisions by the analyst on consolidation of FRNs and lines with small associated tonnages (10 tons or less; 20 tons or less, etc.).

AGGREGATION

The aggregation program will provide for aggregating shipments by category (ammunition, unit cargo, and resupply cargo). This program will aggregate shipments with a common origin and destination to a level specified by the analyst (10 short tons or 20 short tons, etc). The aggregation will be by LAD up to the tonnage level specified by the analyst. For example, assume that ammunition is to be aggregated to the 10-ton level. The proposed program will look at all ammunition requirements with a common origin and destination in LAD sequence and aggregate all requirements of less than 10 tons until a sum of at least 10 tons is reached. Provision will be made for printing out the subsumed FRNs and lines and for updating temporarily the tonnage for the last FRN or line that caused the aggregation to equal or exceed 10 tons. Provisions will also be made for correcting the modified FRNs and lines and inclusion of the subsumed FRNs and lines for inclusion in the tape for preparation of L cards.

MODULAR SCHEDULING

A program to permit scheduling by modules will be provided. The proposed modules are: (1) air passengers, (2) ammunition, and (3) cargo (including both unit and resupply).

This modular scheduling is based on the following assumptions:

- The movement of air passengers from any origin to the APOE is by bus or commercial air and so does not influence the outloading or receipt of cargo at the origin.
- The outloading capacity for ammunition at the three or more origins also used for other types of cargo can be separated from the capacity to outload other types of cargo.
- Movement of unit cargo takes priority over resupply cargo at any given origin.

The modular program is basically a sorting scheme to permit independent use of scheduling programs by the analysts working in each of the areas included in the modules.

EFFORT

The Analysis and Aggregation program outlined above can be developed to the point of implementation in about 4 calendar months using about 7 person-months of effort at an estimated cost of $40,000. The work to be accomplished will include:

- Development and debugging of programs
- Documentation of all programs to include instructions for analysts
- Installation on government equipment and training of government operators

The above estimates are based on the following assumptions:

- The government will make available time on the government equipment on which the programs are to be installed on a reasonable turnaround basis. This machine time will be at no cost to GRC.
- The government will furnish to GRC a classified Master Requirement Record for final program testing.

TABLE 2

TOTAL PLAN REQUIREMENTS BY LAD
IN TONS AND AIR PASSENGERS[1]

	LAD					
	Total	0-10	11-20	21-30	...	171-180[2]
Ammunition, total						
Short						
Measurement						
Sea						
Short						
Measurement						
Air						
Short						
Measurement						
Unit cargo, total						
Short						
Measurement						
Sea						
Short						
Measurement						
Air						
Short						
Measurement						
Resupply cargo, total						
Short						
Measurement						
Sea						
Short						
Measurement						
Air						
Short						
Measurement						
Grand total						
Short						
Measurement						
Sea						
Short						
Measurement						
Air						
Short						
Measurement						
Passengers, air (number)						

[1]Additional commodities will be added if requested by MTMC.

[2]LAD increments will be specified by the analyst.

TABLES 3-10

(TOTAL PLAN) (AMMUNITION) (UNIT CARGO) (RESUPPLY CARGO)
TONNAGES, REQUIRED BY ORIGIN AND DESTINATION[1]
(SEA) (AIR) MOVEMENT

	All Destinations	Destination$_1$	Destination$_2$	...	Destination$_n$
All origins, total					
Short					
Measurement					
Origin$_1$					
Short					
Measurement					
⋮					
Origin$_n$					
Short					
Measurement					

[1] Additional commodities will be added if requested by MTMC.

TABLE 11-18

(TOTAL PLAN) (AMMUNITION) (UNIT CARGO) (RESUPPLY CARGO)
REQUIRED FROM ORIGIN, BY LAD IN TONS (SEA) (AIR) MOVEMENT

	LAD				
	0-10	11-20	21-30	...	171-180[1]
All origins					
Short					
Measurement					
Origin_1					
Short					
Measurement					
⋮					
Origin_n					
Short					
Measurement					

[1]LAD increments will be specified by the analyst.

TABLES 19-26

(TOTAL PLAN) (AMMUNITION) (UNIT CARGO) (RESUPPLY CARGO)
TIME REQUIRED AT DESTINATION, TIME PHASED
BY LAD IN TONS (SEA) (AIR) MOVEMENT

	LAD				
	0-10	11-20	21-30	...	171-180[1]
All destinations					
Short					
Measurement					
Destination_1					
Short					
Measurement					
⋮					
Destination_n					
Short					
Measurement					

[1] LAD increments will be specified by the analyst.

TABLE 27-34

(TOTAL PLAN) (AMMUNITION) (RESUPPLY CARGO) (UNIT CARGO)
TONNAGES AND FRNs REQUIRED BY ORIGIN AND DESTINATION
(SEA) (AIR) MOVEMENT

	All Destinations	Destinations$_1$	Destinations$_2$	...	Destination$_n$
All origins					
FRNs* < 10.1 tons (number)					
FRNs < 10.1 tons (tons)					
FRNs 10.1-20.0 tons (number)					
FRNs 10.1-20.0 tons (tons)					
FRNs > 20.0 tons (number)					
FRNs > 20.0 tons (tons)					
All FRNs (number)					
All FRNs (tons)					
% FRNs < 10.1 (number)					
% FRNs < 10.1 (tons)					
% FRNs 10.1-20.0 tons (number)					
% FRNs 10.1-20.0 tons (tons)					
Origin$_1$					
Same as above					
. . .					
Origin$_n$					
Same as above					

*or lines

(Note: The values in the stub for sorting by tonnages can be varied by the analyst.)

SECTION 3

NETWORK MODEL OPTION

GENERAL DESCRIPTION

A model, to be called NETWORK, is proposed to perform the movement scheduling now performed by MAPS. NETWORK will be adapted from proven existing transportation movement algorithms to eliminate most of the defects in the MAPS scheduling programs that are listed in Table 1. The existence of these proven algorithms permits the development of NETWORK rapidly and at low cost as compared to development of a completely new movement scheduling model. The advantages and disadvantages of NETWORK, as compared to MAPS scheduling system, are listed in Table 35.

NETWORK will be compatible with the Quick Analysis and Aggregation programs described in Section 2. The efficiency of NETWORK will be improved if the aggregation programs are used. The expected efficiencies are reduced running time, reduced requirements for core storage, and greater flexibility in the use of NETWORK by modular movement scheduling (e.g., air passengers, ammunition, and other cargo).

TABLE 35

MAJOR ADVANTAGES AND DISADVANTAGES OF NETWORK
AS COMPARED TO MAPS SCHEDULING

STRUCTURAL ADVANTAGES

- Computer running time significantly reduced (about 8 hours for 60,000 movement requirements)
- Schedules either single or multi-theater movements in one run
- Schedules both mobilization and deployment movements either separately or in combination
- Provides the earliest day of arrival at the POD without violating any throughput or availability constraints for movements that cannot meet the LAD
- Can store intermediate information during a run to permit additional requirements on subsequent runs to be included in final tables. Correction of previously moved requirements may require rerunning of entire module or plan to produce correct tables
- Identifies specific constraints that prevent arrival at POD by LAD
- Can produce interim reports
- Can cycle notional ships for second trips given availability at first port (if current assumptions on ship availability are to be varied and explicit availability data are not available)
- Provides a capability to vary total availability of resources (e.g., ships, rail cars, etc.) to perform the movement of requirements

LOGIC ADVANTAGES

- Provides for minimum transit time through a set of preferred POEs
- Provides for trade-off between rail and motor capabilities when both modes are used simultaneously at origins
- Constrains ports in terms of daily ship loading capacity by type of ship (e.g., break bulk, container, RO/RO, etc.)

USAGE ADVANTAGES

- Warnings (flags) can either be resolved when they occur in the scheduling sequence or with residual resources, as specified by the analyst, to estimate arrival date at the destination

DISADVANTAGES

- Requires a new data base derived from data in the Master Requirement Record and the MTMC planning factors
- Requires large amounts of core unless modularity (air passengers) ammunition, etc.) is instituted. Without modularity about 75,000 words of core required for a large 90-day plan. With modularity, core requirements reduced to about 40,000 words

BASIC METHODOLOGY

NETWORK is based on the analysis of a transportation system defined in terms of links and nodes. As explained in Section 1, there are proven algorithms for such networks that can be adapted to meet the MTMC needs for mobilization and deployment movement analyses. A type network is shown in Figure 1.

The algorithms are used to determine the optimum path (least time) from origin to destination without violating the specified constraints of the system. The constraints to be incorporated into the NETWORK model will include, but not be limited to:

- Maximum daily transfer capability to include trade-off between elements of mixed modes
- Maximum daily link capacity, if any
- Ship, rail, and truck capacities (cargo and speeds) and availability
- Ready-to-load dates

The output of the algorithms is the optimal arrival time at the destination for each movement requirement. In the NETWORK model the destination will be defined as either the Air POE, Sea POD, or mobilization station.

The NETWORK algorithms will be programmed in FORTRAN to take advantage of the language's efficiency in performing mathematical calculations and to capitalize on the existing FORTRAN programs.

The NETWORK model can be programmed for either batch or interactive operation assuming the computer equipment is available. If the MTMC wants rapid computer turnaround to develop schedules as quickly as possible, then provision must be made for the modification of data, by the analyst, through terminals. These terminals could be either hard copy or cathode-ray tubes depending on disposition of the output.

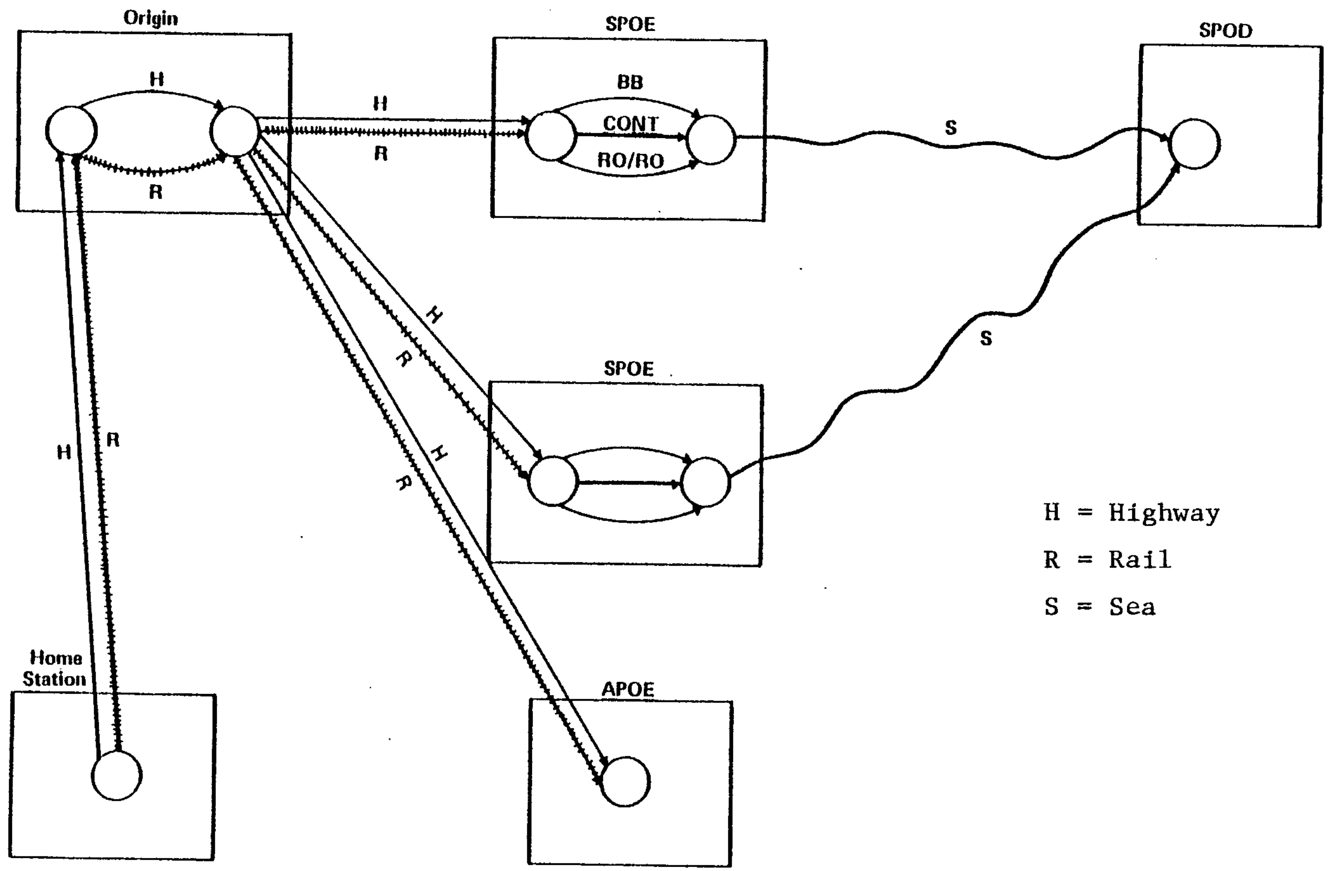

Figure 1. Sample Network

It is recommended that the model be run interactively or with remote job entry so that the analyst can provide immediate gross direction to the model leaving the detailed directions (through data) to be entered off line at the convenience of the analyst. The system will not succeed if the analyst must sit at a terminal, while the program is running, and answer a large number of questions about the minor decisions that the model will have to consider. The proper time to plan the deployment is before the run has started not during the execution.

OUTPUTS

Outputs from the NETWORK model will be held to the minimum essential volume to reduce the burden on the analyst. However, the model can produce vast amounts of data which can be stored for the production of special reports. The first phase of the installation of the NETWORK model will not include the production of special reports. After the MTMC analysts gain experience with the model, they will be in a better position to determine which special reports are required to accomplish their tasks. Special tables can be programmed in FORTRAN or COBOL as desired or consideration can be given to the use of the Report Program Generator (RPG) for the Honeywell computer. The RPG is a general-purpose report production program which, if available, can probably produce the special reports when needed.

The minimum output from the model will consist of the three reports shown in Figure 2. These reports are described below.

Movement Summary

This report is designed to provide the required data for "L" cards. It will consist of the results of the scheduling run plus additional information from the Master Requirement Record to provide the analyst with a summary report of the results of the scheduling process. The report will contain, as a minimum, the data listed below.

Report 1

MOVEMENT SUMMARY

FRN	AVAIL	ORIGIN	DEPART ORIGIN	SPOE	ARRIVE SPOE	DEST.	ARRIVE DEST.	NOTE

Report 2

RESIDUAL LINK CAPACITIES

LINK NO.	FROM NODE	TO NODE	DAY 1	2	3	4	5 - - - - - - - - - - - - -

Report 3

VEHICLE REQUIREMENTS

VEHICLE NO.	NAME	DAY 1	2	3	4	5 - - - - - - - - - - - - - -

Figure 2. Minimum Reports from the NETWORK Model

FRN	-	the FRN or line number of the movement requirement
AVAIL	-	the Ready-to-Load day of the movement
ORIGIN	-	the geolocation code and name
DEPART ORIGIN	-	the day the movement is scheduled to clear the origin
SPOE	-	the geolocation code and name (if movement by sea)
ARRIVE SPOE	-	the day of arrival at the SPOE
DEST	-	the geolocation code and name of the mobilization station, APOE or SPOD
ARRIVE DEST	-	the day of arrival at the destination as defined above
NOTE	-	indicator of delays in the movement which might cause the movement to be flagged by MSC

Additional information from the Master Requirement Record may be added to improve the value of the report for the analyst.

Residual Link Capacities

At a minimum, this report will provide the daily residual capacity at the origin and port links of the network after all movement requirements have been scheduled. Since all origin and port constraints are expressed as link capacities, this report will allow the analyst to determine bottlenecks in the system. Link capacity will be expressed in terms of rail cars, trucks, tonnages (by type) as specified by the MTMC during the model design. The MTMC will be requested to determine during the model design if the output should be suppressed for links that were not used or used only below a specified capacity. Such a specification would contribute to maintaining the volume of the output to a useful level. The report will contain the data listed below.

LINK NO.	- the link number assigned by the NETWORK program. Link numbers are assigned sequentially from 1 to the number of links in the network
FROM NODE	- the geolocation code of the node at the beginning of the link
TO NODE	- the geolocation code of the node at the end of the link
DAY	- the residual capacity by day (in terms to be specified by the MTMC)

Vehicle Requirements

This report will show the number of vehicles by type and by day which are required to meet the total schedule produced by the model. Vehicle constraints (in terms of maximum available vehicles per day) may be applied to the scheduling process if desired.

VEHICLE NO.	- The vehicle class number as shown in Table 36.
VEHICLE NAME	- The name of the vehicle class as shown in Table 36.
DAY	- The number of vehicles used during that day

TABLE 36

MODES AND VEHICLES

Mode	Vehicle class
Origin loading - rail	Rail loading
Origin loading - highway	Highway loading
Transportation - rail	Fast train; slow train
Transportation - highway	Fast truck; slow truck; bus
Transportation - sea	Notional ship
Port constraint - break bulk	Break bulk loading
Port constraint - container	Container loading
Port constraint - RO/RO	RO/RO loading

INPUTS

The NETWORK model does not require any more data than the current MAPS system. However, the data must be structured differently to take advantage of the network analysis technique. Thus, the network requires links of the proper mode, length, from and to nodes, and capacity to represent the data now contained in tables or calculated. Examples of such data are distances from origins to ports, sea distances, origin throughput constraints, port throughput constraints, etc. Consequently, effort will have to be devoted to programming a preprocessor to abstract data from the current or new data bases and reformat it into a network for input to the model.

Network

Figure 1 shows a portion of the network representation of the deployment scheduling problem. All locations with constraints (origins and SPOEs) are represented by two nodes with the constraint(s) shown as a link between them. Thus, the origin is shown with rail and highway links to represent loading constraints while the SPOEs are shown with cargo-loading constraints for break bulk, container, and RO/RO ships. The allowable POEs for each origin are designated by the existence of a link from the origin to the POE. The absence of a link between nodes prevents movement between those nodes. In a similar manner, the absence of a link of a particular mode between two nodes prevents movements on that mode between the nodes in questions. For example, if there is only a highway link (no rail link) between an origin and a POE, no rail movement can be made between those nodes.

Since the model determines the fastest time between origin and destination, allowable POEs for both a European and Asian deployment should be included in the network. The model will then be able to handle multiple theaters during the same run, always selecting the fastest route.

If links are also shown between home stations and mobilization stations, the network will handle the mobilization either separately or in combination with the single or multiple theater deployment.

As previously stated, the network consists of links and nodes. Links are explicitly defined; nodes are implied from the descriptions of the links. Each link is defined in terms of the following data:

- Mode - one of the modes selected from among those shown in Table 36
- Length - the length of the link in miles
- Capacity - the maximum permitted flow over the link either in tons or vehicles per day. A link has infinite capacity if it cannot constrain movements
- From node - the node at the entrance of the link (geolocation code)
- To node - the exiting node (geolocation code)
- Node coordinates - these may be used to calculate the length of the link (optional)
- Identification - a unique link identification code (optional)

<u>Movement Requirements</u>

The movement requirements for the network model will be abstracted from the Master Requirement Record prepared by the MTMC from the operations plan and the JOPS data base. The minimum data requirements are:

- Ident - a unique identification of the movement requirement
- Origin - expressed as a geolocation code. Must have appeared on at least one link
- Destination - expressed as a geolocation code. This data item might be a POD or mobilization station depending on the type of run. Must have appeared on at least one link

- Ready to load date - the earliest day the movement is available for loading at its origin
- Mode - the desired mode(s) and means for movement from origin to destination
- Earliest arrival date the movement is permitted at destination

Parameters

Parameters are used to describe the transportation system in the detail required by the model. These include:

- Vehicle speeds - the speed at which vehicles move over the network in miles/day
- Vehicle capacity - in tons/vehicle. Used for conversion from tons to number of vehicles: for Pax; people/vehicle
- Vehicle assignment - assigns vehicles to modes (see Table 36)
- Vehicle constraints - the number of each class of vehicle available for the movement scheduling
- Modification - modifications to vary the link capacities and/or number of vehicles by day

LOGIC

At least two programs will be required to perform the scheduling; a Preprocessor and the NETWORK model. A brief description of the logic of each follows:

Preprocesscr

The Preprocessor will be designed to create the network and movement requirements files from data readily available to MTMC and with little human intervention.

Network. The properties for the definition of links have previously been listed. They will be obtained as follows:

- Mode - One of the loading, transportation, or constraint modes listed in Table 36.
- Length - The length of each link will be obtained from either distance tables or calculated from the coordinates of the endpoint nodes. Distances will be required between origins and their allowable ports and between seaports as a function of the transportation mode. Constraint links will have either a zero or nominal length depending on whether or not a delay is desired at the node.
- Capacity - Obtained from each origin's loading constraints by day and transportation mode and for each port by day and type of ship. The units of capacity will either be tons or vehicles per day.
- Nodes - Geolocation codes associated with link end nodes will be obtained from the data used to determine the length of the link.

Movement Requirements. The data required for each movement requirement have previously been defined. They will be created as follows:

- Identification - Will be obtained from the Master Requirement Record. Either the FRN or line number will be used.
- Origin - Obtained from the Master Requirement Record.
- Destination - Obtained from the Master Requirement Record.
- Ready to load date - Obtained from the Master Requirement Record.
- Mode - the NETWORK model requires the designation of mode in terms of the numbers of vehicles (or tonnage) of each vehicle class allowed to carry the movement. The vehicle classes are shown in Table 36. Each movement requirement must be permitted to move on more than one vehicle class in order to find an optimum (or any) path between its origin and destination. The following data items

contained in the Master Requirement Record will be used to designate the allowable vehicle classes: the distance between the origin and the port, the commodity type, the specified mode and means, the tonnage to be moved, and other items as may be required.

- No-sooner-than-date - The EAD from the Master Requirement Record.

For example, suppose the requirement is to move 100 tons of ammunition from CONUS origin to an overseas destination by sea. The requirement may move by rail or highway to the SPOE. The following vehicle types will be required.

Origin loading. Rail will be permitted. The movement requirement consumes 2.5 units of origin loading capacity if each rail car holds 40 tons. Highway will also be permitted. Five units of highway loading capacity will be consumed if each truck holds 20 tons. The specification of the number of tons per vehicle is done in the parameters section of the input to NETWORK.

Transportation. If the movement to the optimum port is less than 700 miles, it will be by fast-moving truck because the tonnage is greater than a truckload. Or if the distance to the optimum port is greater than 700 miles it will move at less than trainload speed (slow train) by rail. Both options must be allowed since the length of the optimum route is unknown until the NETWORK model is run. Ship travel time must also be allowed because the movement is permitted to move by sea.

Port constraint. The vehicles specified will depend on the data in the Master Requirement File. If the ammunition is containerized it will be permitted to use the container vehicle; otherwise it must use the break bulk vehicle.

In this example, at least six vehicle classes were permitted based on the parameters of the movement requirement. Different movements will have different allowable vehicle classes. For example, the movement of tracked vehicles by highway would not be permitted regardless of the distance to the port. The movement of people by bus would not be constrained by the loading capability of its origin because people load themselves.

NETWORK provides analytical capabilities for the MTMC which are now lacking. Suppose a movement were permitted to move either by break bulk or container classes and the two ship classes were available (notional break bulk and notional container), then the model would decide which ship class to use based on its speed, the remaining capacity of the port to load the class of ship and the availability of ships of the proper class. Thus, the model would not only select the best port but would decide whether the cargo should be containerized or break bulk, all without violating any of the prescribed constraints of the transportation system.

NETWORK Model

This portion of the report is designed to provide some insights into the logic of the NETWORK model as currently conceived. Changes to the logic described will be required to meet the special needs of the MTMC as determined during the model design.

- PARAMETERS - The parameters portion of the input is read, stored, and printed for reference by the analyst.
- LINKS - The links which comprise the network are read, and their transit time calculated. All links are checked for valid data and printed, possibly with an error message. All links meeting the validity checks are numbered sequentially. This is the link number which will be used by the model in outputs which make reference to a particular link.

- SETUP - the link data are sorted and various pointers set to reduce the time needed to determine the least time path from origin to destination.
- MOVEMENT - Movement requirements are read one at a time; until the end of file is reached. Control passes to PATH except after the reading of the last movement when control passes to POST.
- PATH - Movement data are checked for validity. Some of the checks include the occurrence of the origin and the destination in the nodes of the network, and flow requirements greater than zero. The algorithm is initialized, and the Dijkstra method is used to determine the optimum path between the origin and destination without violating any of the constraints of the transportation system.
- PUSH - Some or all of the movement is pushed along the optimum path, adjusting the link capacities and numbers of vehicles used. The amount moved may be less than the total requirement because of a binding constraint, i.e., the origin capacity to load trucks has been exhausted. If the movement is finished then one line of the Movement Summary report is created and control passes to MOVEMENT. If the total tonnage of the current movement requirement has not been completed, then control passes to PATH.
- POST - At this point all the movements have been completed. The three reports previously described (Movement summary, Residual Link Capacity, and Vehicle Requirements) are created and printed. A portion of the core is saved to permit continuation of the run at a future time when, perhaps, additional movement requirements are ready for processing. By this technique additional runs can be made with the assurance that all tables will be correctly updated, taking into account the additional movements.

BERTHING

Assigning cargo to individual berths within a port is not performed during deployment planning by the NETWORK model. This phase of the problem is more properly done during execution planning based on the amount and type of cargo flowing through a port on a given day. This type of output will be available from the NETWORK model.

Assigning cargo to berths is now required because in MAPS ships are underloaded when they have to leave their berths at the end of their time on berth period. Thus, manual adjustments must be made to try to fill ships and the remaining berth capacity must be known.

The problem of underloaded ships will be treated in the NETWORK model by reducing the numbers of POEs and berths available for the movement of cargo. It appears that MTMC uses all available ports for the movement of cargo, thus scattering their movements in bits and pieces in an effort to meet LADs at the expense of reasonable shiploads. Reducing the number of ports to, perhaps, the CINC's desired ports, the designation of consolidation ports, and the use of aggregation programs described in Section 2, should increase the daily flow through each port, thus giving a higher probability of meeting minimum ship loads. Experiments should be performed to determine the maximum number of ports needed to provide reasonable ship loads at levels specified by the MTMC, perhaps in coordination with the MSC.

EFFORT

It is estimated that the NETWORK model can be developed, installed, and documented in about 11 calendar months (20 person-months) at a cost of approximately $148,000.

In the sequence of work, priority would be given to the Preprocessor program data requirements, modification of existing algorithms and installation of the NETWORK model. It is estimated that the MTMC could have a working version of the model in about 6 calendar months after award of contract. This would permit the use of the model, under

supervision of GRC, for testing, familiarization, and actual movement scheduling. The remaining effort will be devoted primarily to the documentation of the Preprocessor and NETWORK programs and the training of the MTMC personnel.

The estimate is based on the following assumptions:

- Approximately 350 connect hours on the MTMC computer will be provided at no cost to GRC, in the unclassified mode. The work can be expedited if the computer can be accessed through telephone-connected terminals.
- The documentation will consist of user's manuals and detailed logic and program descriptions. The documentation standards will be established in coordination with the MTMC. It is anticipated that WWMCCS standards will be a prime candidate for consideration.
- The costs include installation on government equipment and training of the analysts who will be using the programs.
- The costs do not include special reports which may be desired by the MTMC beyond those mentioned in the description of the NETWORK model.
- The MTMC will provide an unclassified portion of a typical Master Requirement Record file.

SECTION 4

RESEARCH OPTION

BACKGROUND

The MAPS program and the suggested NETWORK model are both simulations that treat each movement requirement sequentially in accord with certain criteria and constraints. In the NETWORK model the concept of the optimization of individual movement schedules (least time) is introduced in an attempt to produce better schedules. The research option takes the scheduling process one step further by attempting to optimize (least time) all the movement requirements within a single total movement schedule. Thus, the technique will be able to evaluate the interactions between movement requirements which neither MAPS nor NETWORK can accomplish. Remember that all optimization is no better than the data being used.

Currently, linear programming models for the optimization of large and complex problems such as those addressed by MAPS and NETWORK are extremely difficult to formulate, if at all possible, and require very long computer run times. Further, the solutions are difficult and time-consuming to decipher because of the encoding of the data, and the aggregation of movement requirements. In order to reduce the complexity of the model, movement requirements are aggregated into as few commodities as possible without destroying the validity of the model.

There have been recent developments in the field of mathematical programming that give promise of permitting relatively rapid formulation and solution of large problems such as the CINC Operation Plans presented to the MTMC. Examples of such recent developments have been reported in operations research literature.[1] Even if a practical mathematical

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[1]Hindelang, Thomas J., and John F. Muth, "A Dynamic Programming Algorithm for Decision CPM Networks," Operations Research, March-April 1979, and Glover, F., J. Hultz, D. Klingman, and J. Stutz, "Generalized Networks: A Fundamental Computer-Based Planning Tool," Management Sciences, August 1978.

programming technique can be found for an optimization model for scheduling movement requirements now handled by MAPS, it will still be necessary to have a supporting simulation model to produce the types of detailed data required from the MTMC by the JCS and for internal planning by the MTMC. This simulation model would be based on the output of the optimization model and would probably be simpler and faster than either MAPS or even the proposed NETWORK model. For example, if the MTMC wants to report the arrival date of a particular ammunition FRN, there must be some disaggregation methodology for identifying the FRN from the solution. A similar situation occurs for all FRNs.

As with all proposed solutions to the MTMC scheduling problem, the optimization technique has both advantages and disadvantages as listed below:

Advantages

- Optimum decisions would be made for the daily operation of each origin (highway, rail or mixed) loading operation
- Minimum ship loads could be specified to insure that all SPOEs have at least a minimum amount of cargo on hand to load a ship. Movements would be routed to provide the ship cargoes, thus in effect automatically consolidating at the POEs.
- Port constraints would be optimized by delaying or rerouting movements
- The selection of seaports for every origin would be optimum, provided origin consolidation could be performed.

Disadvantages

- Limited numbers of commodities
- The requirement for three programs; one to create the input matrix, a program to produce optimum schedules, and a program to interpret the results to produce the detailed output required by the MTMC.

- The concept of the perfect knowledge of the program disturbs many people. Can optimum schedules be derived from approximate data? There is no possibility that such a schedule could be attained in the real world.
- The scheduling of movements is still being suboptimized because the MTMC could not optimize the sealift portion of the schedule. All the optimization being performed by MTMC would be wasted if MSC could not take advantage of these optimum schedules.

SCOPE OF PROPOSED WORK

The work will consist of the tasks described below.

Task 1 - Data Gathering

Literature search and interviews with experts in the field.

Task 2: Feasibility Assessment

Based on the results of Task 1 and the use of a few consultants, an assessment will be made of the feasibility of any of the new optimization techniques for use in scheduling movements. This assessment will include (1) estimates of the time and cost to develop and implement such an optimization model, (2) the input requirements, (3) the expected outputs, (4) compatibility with the existing simulation model, and (5) need, if any, of a new simulation model.

Task 3 - Documentation

A complete written report, including recommendations, will be prepared.

EFFORT

It is estimated that the proposed work can be accomplished in about 3 calendar months with about the equivalent of 2 person/months at an estimated cost of $18,000. This estimate includes the services of Dr. Peter B. McWhite of GRC and of Dr. Darwin Klingman, a GRC consultant, and other consultants.

APPENDIX A

TASKING STATEMENT

DSS-W TASKING STATEMENT

GENERAL TASK DEFINITION:

The purpose of this task order is to provide technical assistance to the Military Traffic Management Command (MTMC) in the development of the capability for the analysis and scheduling of CONUS movements by computer for mobilization and deployment planning in support of operation planning or other special projects.

TASK DEFINITION:

1. Provide technical assistance to MTMC in determining the approach to use to acquire the desired capability, its schedule, and cost.

2. Analyze the requirements of the MTMC in the area of CONUS movement scheduling in relation to its mission and the requirements placed on the Command by DOD agencies.

3. Determine the existing MTMC environment within which the scheduling program must operate. This includes the computer, operating system, data bases and other available software.

4. Investigate the applicable mathematical techniques and existing software capable of meeting the requirements for a CONUS movement scheduling model.

5. Prepare a formal report describing the recommended model functionally and technically to include description of how the model addresses discrete facets of MTMC functional requirements. The report must include estimated time and cost for model design and development, or conversion and modification in consideration of subsequent tasking from MTMC.

6. Provide other technical assistance as requested by the COTR.

The anticipated starting date of this task is 20 April 1979. All technical work under this task will be completed by 12 July 1979.

GENERAL PROVISIONS:

1. Progress on this task, along with resource consumption, will be reported in regular monthly and special reports as required.

2. A draft report, documenting all work performed under this task will be provided to the COTR in two copies not later than 12 July 1979 and a final report within 30 days after receipt of approved draft report.

MANAGEMENT:

DSS-W COTR	Mr. William S. Boone	697-3686

COORDINATION:

MTMC	Peter H. W. van der Goes Major, USAF	756-2150

Peter H. W. van der Goes

APPENDIX B

MAPS DEVELOPMENT

Extracted from Larry Bobo, "Systems Description for Mobility Analysis and Planning System (MAPS)," MTMC, 1 March 1979

APPENDIX B
MAPS DEVELOPMENT

Section 1. Introduction

This section defines objectives, references and background for MT-SY input to the MAPS II Analysis and Design Task Force.

1. Purpose. The objectives of the MODS system description contained in this document are to describe the system and influences sufficiently to assist the development of a concise Detailed Functional System Requirement (DFSR) for the eventual design of a state-of-the-art MTMC Mobility Analysis and Planning System, and Intra-CONUS System, for time-sensitive planning and interaction with JCS, MAC, MSC and other Players of JOPS in the WWMCCS and WIN environment.

2. Reference Documents. The following documents are referenced as applicable influence and guidance for the MODS systems MAPS and Intra-CONUS:

a. JCS Pub 6, Vol II, Part 11, Chapter 1, DEPREP

b. JCS Pub 6, Vol II, Part 14, Chapter 5, INCONREP

c. NMCSSC CSM UM 185-75 GEOGRAPHIC LOCATIONS CODES (GEOFILE)

d. WWMCCS J7204-OM-DEPDA

3. Background. The Mobility Analysis and Planning System (MAPS) began with the concept outlined in 1966. The design, programming and testing was completed by October of 1968 for execution on a Burroughs 5500 system at the Eastern Area. Testing of the system, with Operation Plan (OPLAN) MOVECAP-68, resulted with the Command estimate of approximately 1.5 saved man-years of manual effort for the MOVECAP plan. MAPS, then called the Military Traffic Management and Terminal Services (MTMTS) Automated Transportation Scheduler (MATCH), was not active between 1968 and 1972 because of JCS review and developmental efforts in the area of Deployment Reporting (DEPREP).

With the installation of a Burroughs 5500 computer at the Headquarters, operation and development of the system was shifted to the Headquarters in 1972.

From 1972 to 1973 the system was used to support two small-to-medium JCS plans; JSCP-74 and Gallant Crew.

During the period of December 1972 through April of 1973 the system was converted to the World Wide Military Command and Control (WWMCCS) Honeywell Computer. This conversion was instrumental in updating the system by:

a. accomodating a greatly revised DEPREP edit

b. moving from a disk/tape environment to a total disk environment

c. introduction of the Command and Control Technical Center (CCTC) developed Deployment Data (DEPDA) file.

d. introduction of MAPS, vice MATCH, with the DA approval for ten basic enhancements; as follows:

ENHANCEMENT	COMPLETED
(1) EAD-RDD Modification	Jun 75
(2) DEPREP Flag ID	Jun 75
(3) Cargo Detail	Jun 75
(4) Shipload Consolidation	Apr 76
(5) Intra-CONUS "Bare Bones"	Aug 76
(6) Cost Model	Deferred
(7) Vehicle Model	Deferred
(8) Port Model	Deferred
(9) VDU Model	Deferred
(10) Requirements Generator	Deferred

Development of the Joint Operation Planning System (JOPS) by the Command and Control Technical Center (CCTC) evidenced the increased JCS concern in the area of Joint Operation Planning. This increased involvement by CINC's, Services and TOA's produced more frequent taskings for MAPS with data volumes three to four times those anticipated during the 1972-73 conversion. The increased frequency, volume and complexity caused the 1975 deferment of five enhancements in order to develop JSCP FY 76 enhancements for:

ENHANCEMENT	COMPLETED
a. Organic Moves	May 76
b. Non Self Deployable Aircraft	May 76
c. Floating Craft	May 76
d. Refined Cargo Detail-Short Tons Less Than Five	May 76
e. Container Ammo Port	Feb 77
f. Intra-CONUS Cargo Detail	May 77
g. Refined Intra-CONUS Inload Reports, Service Unique MVMT Tables, Equipment Summary	Sep 78
h. Deployment/Mobilization Comparison	Sep 78

Increased operational demands placed on MAPS along with unrealistic milestone for system enhancement rendered the system vulnerable to excessively long execution times, a near unmanageable state and a state of questionable reliability.

Because of the commonality of data between DEPREP and INCONREP, the time-sensitive developmental effort and customer recommendation and guidance, the Intra-CONUS system was developed through MAPS program cannibalization where

possible. For report generation this approach was manageable and provided an expedient approach to providing MAPS like products. In the areas of scheduling and files updating it required experimentation which grew extremely tedious because of excessive and incompatible logic and absent or unnecessary paramaters and constraints. The two main conflicts; 1) MAPS reverse scheduling vs Intra-CONUS forward scheduling and 2) MAPS outloading at installation/depot vs Intra-CONUS inloading at mobilization station.

MTMC concern for more timely planning response, flexibility in applying planner judgement, and the inability to intervene during MAPS execution led to the conclusion in August of 1978 that the system required total redesign. On August 7, 1978 the Vice Commander, MTMC directed the formation of a MAPS II Analysis and Design Task Force with the specific objective of developing a Detailed Functional System Requirement (DFSR) for a time-sensitive Mobility Analysis and Planning System. The concensus was that a moratorium would exist on the current MAPS and Intra-CONUS enhancement with maximum priority given to DFSR and System development.